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5 International Invention: Implications for Technology Market Analysis

Robert E. Evenson

This paper examines international data on patented inventions, R & D expenditures, and scientists and engineers engaged in inventive activity. It reaches two principal conclusions which have some bearing on the modeling of firm behavior and possibly on policy actions which might be taken toward the stimulation of invention. First, the data show comparative advantage patterns in invention similar to patterns observed in products. The production of pioneering invention is concentrated in certain firms located in countries with the best economic laboratories for invention. Large parts of industry in most countries import inventions and concentrate on adaptive invention rather than investing heavily in R & D. Second, the data show that inventions per scientist and engineer have declined from the late 1960s to the late 1970s in almost all of the fifty countries for which data are available.

These conclusions are based on data on patented inventions from many countries. To defend them one must argue not only that patented inventions are a reasonable proxy for inventions in general but also that this proxy relationship has a reasonable degree of international comparability. Further, to support the second conclusion one must argue that no major changes in the proxy relationship have taken place over the past ten to fifteen years.

These conclusions have a threefold defense. First, because of international conventions regarding patenting and the requirements for patentability and the high degree of international patenting (i.e., patents granted to foreigners), a general standardized legal basis for patenting exists. This is further standardized by the widespread adoption of the International Patent Classification system. Second, patent data show regular patterns

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and consistency. Patenting is highly correlated with R & D spending in the United States and other countries where reasonably good data exist. Most patents granted are subsequently cited as "next best art" in the United States and other countries with citation requirements.[1] Patent infringement cases are important enough in most countries to indicate that patents are not trivial or irrelevant. Finally, there is little evidence that standards of patentability have changed drastically in recent years in most major centers of invention. Nor is there evidence to suggest that firms in almost all industries in almost every country of the world have changed their policy toward obtaining patents to a degree sufficient to explain the data.

Section 5.1 of this paper presents a descriptive summary of patent data and discusses different types of patent systems and standards for patentability. Section 5.2 shows the trade patterns of the data. Section 5.3 provides data supporting the conclusion that inventions per scientist and engineer have declined and argues the case for interpreting this phenomenon as the result of exhaustion of "invention potential." Section 5.4 discusses implications for technology market analysis.

5.1 International Invention: A Descriptive Summary

To interpret data on patenting it is first useful to summarize the options open to a firm to alter the technology it uses:

(1) It can engage in fundamental or basic research to obtain findings that will improve the efficiency of its more applied research.

(2) It can engage in applied research designed to invent a new product or process and bring it to the development stage.

(3) It can engage in the testing, pilot production, and plant design work required to bring inventions developed by its own applied research into use.

(4) It can purchase inventions (or in the case of unprotected inventions, imitate them) and engage in strictly adaptive research and development bringing them into use.

(5) It can purchase semi- or fully developed inventions "embodied" in machines, chemicals, or "turnkey" plants, making only minor modifications of other inventions.

Of these activities, (1) produces few patentable inventions; (2) produces most conventional or utility patents; (3) produces a number of utility patents (especially of process inventions) and a number of "petty" patents (utility models); (4) produces most petty patents; and (5) generally does not produce patented inventions.

1. Wright and Evenson (1980) reported that approximately 75 percent of the patents granted in specialized chemical fields (oils and food chemicals) are subsequently cited as next best art in other patents.

Legal systems and industrial organization policies in different countries influence the types of inventive activities undertaken by firms and the patentability of inventions. Some countries pursue policies which encourage the holding of inventions in trade secrecy. When industrial organization structures effectively discourage competition in an industry, firms may have little incentive to sell new technology in direct form and will attempt to capture rents through the sale of new technology embodied in products. This tendency is reinforced by trade secrecy laws which provide penalties for the pirating of trade secrets.

The traditional "invention patent" is designed to provide an alternative form of protection by granting the inventor legal means to prevent others from copying or using the invention without permission for a limited period of time (usually fifteen years). Invention patent documents are required to provide an "enabling disclosure" which sufficiently describes the invention to enable one skilled in the technology field to replicate or make the invention.[2]

Three fundamental requirements must be met by an invention to qualify for the *standard invention patent*:

(1) The invention must be "novel."

(2) The invention must be "useful."

(3) The invention must exhibit an "inventive step" (i.e., it must be unobvious to practitioners skilled in the technology field).

These requirements are important in understanding international patent data when considered in conjunction with international patent "conventions," chiefly the Paris Convention. Membership in these conventions generally requires: (1) that the three requirements for patentability be judged by international standards and (2) that member countries grant patent protection to inventors from other countries provided these standards are met.[3]

An important alternative to the invention patent used in some countries is a *"petty" patent or utility model*. Petty patents generally have a very weak inventive step requirement and in practical terms do not always require novelty against the world's inventions but only against national or regional inventions. In addition, *design patents*, which do not require inventive steps and have relatively weak usefulness require-

2. The legal literature sees this enabling disclosure, which enables or induces further inventions by others, as an important part of the bargain in which monopoly rights are granted in return for disclosure. (Economists, by contrast, see invention incentives as the principal benefit obtained in the bargain.)

3. I will argue in the final section of this paper that membership in international conventions has been very costly (and unwise) for many countries. The cost of searching the world's patent literature to establish novelty is high, and many small countries cannot adequately undertake this task. Furthermore, adhering to a strong international standard of the inventive step requirement effectively removes patent protection from "adaptive" inventions which are about the only types of inventions many developing countries can produce.

ments, are granted by most countries. *Trademarks*, which require only novelty, are likewise granted by most countries. In addition, a number of countries also grant *plant patents*, primarily for asexually reproduced plants.

Table 5.1 provides data for forty-nine countries on numbers of invention patents granted during four periods: 1967, 1971, 1976, and 1980. The countries have been grouped into six classes: (1) industrialized market economies with moderate to rapid growth rates over the past twenty years; (2) industrialized market economies with slow growth rates; (3) semi-industrialized economies with rapid growth rates; (4) semi-industrialized economies with slow to moderate growth rates; (5) middle-to-low-income developing economies; and (6) industrialized planned economies.[4]

Reference to the table will reveal a few anomalies, particularly for the developing countries where some data are missing. Table 5.9 provides a summary by type of economy and a number of generalizations are best drawn at that level. In discussing this and the next several tables attention will be given to individual country data. Table 5.1 shows that the relative ranking of patenting by national inventors has changed appreciably over the period. The United States was the clear leader in 1967 with more than twice as many patents granted as the Soviet Union in second place. France, Japan, East Germany and the United Kingdom followed. By 1980 both the Soviet Union and Japan had surpassed the United States. West Germany had moved into fourth place, with both France and the United Kingdom experiencing substantial declines in patents granted to nationals.

Patents granted to nationals in the United States were only 72 percent of the 1967 level in 1980 (only 60 percent in 1979). For all other industrialized market economies, patents granted to nationals actually increased slightly (2 percent) from 1967–1980. Patents granted to foreigners in the United States rose by 71 percent over the period. For other industrialized nations, patents granted to foreigners declined to only 66 percent of the 1967 level (about 43 percent of this decline was attributable to the decline in patenting abroad by U.S. inventors). In consequence the share of foreigner's patenting in the United States rose from 22 percent in 1967 to 40 percent in 1980.

Of the industrialized economies both Japan and West Germany markedly expanded patenting activity at home. Only Japan, among large industrialized nations, realized a significant expansion of patenting abroad. The United States continued to be the dominant country in patenting abroad with West Germany, Japan, and France following.[5]

4. These classifications are based on World Bank (1980).

5. Patenting abroad is influenced by cost considerations. The European countries have recently introduced the Europatent which provides low-cost patent protection in a group of

Table 5.1 **Invention Patents Granted by Country: Selected Years**

	Patents Granted to Nationals				Patents Granted to Foreigners				Patents Granted to Nationals in Foreign Countries			
	1967	1971	1976	1980	1967	1971	1976	1980	1967	1971	1976	1980
Industrialized Market Economies												
Moderate to Rapid Growth												
Japan	13,877	24,759	32,465	38,032	6,896	11,652	7,582	8,074	6,843	15,832	20,246	20,663
Austria	1,188	1,230	1,177	1,227	6,896	7,460	5,235	4,745	1,913	2,399	1,065	1,669
France	15,246	13,696	8,420	8,433	31,749	37,760	21,334	19,622	14,393	17,150	12,677	12,511
Denmark	338	252	208	192	2,002	2,212	2,068	1,453	1,165	1,650	1,217	1,103
W. Germany	5,126	8,295	10,395	9,826	8,300	9,854	10,570	10,362	41,775	44,862	37,316	33,708
Belgium	1,586	1,345	1,034	837	15,041	15,004	12,110	5,081	2,701	2,894	1,905	1,720
Norway	225	386	210	276	1,831	2,343	1,883	1,843	618	658	617	549
Netherlands	322	318	370	417	1,913	2,396	3,219	2,907	7,283	8,745	5,901	5,964
Slow Growth												
Canada	1,263	1,587	1,301	1,503	24,573	27,655	20,449	22,392	2,789	3,201	2,661	2,200
Italy	9,076	4,320	—	1,810	26,180	13,180	—	6,190	5,621	6,749	5,416	5,877
Ireland	28	16	27	24	635	788	1,055	1,407	113	151	146	106
Switzerland	5,388	4,165	3,482	1,475	16,462	11,914	8,818	4,486	12,452	15,409	10,954	9,827
Sweden	1,776	2,245	1,888	1,394	7,532	7,748	6,956	3,604	5,031	6,327	5,719	4,769
United States	51,274	55,988	44,162	37,152	14,378	22,328	26,074	24,675	73,960	87,589	90,273	54,360
Australia	752	979	910	620	10,371	9,662	10,074	7,805	905	986	1,065	2,690
United Kingdom	9,807	10,376	8,855	5,158	28,983	31,178	30,942	18,646	17,579	21,179	14,072	11,140
Finland	231	350	291	439	739	1,312	912	1,467	345	559	650	928
New Zealand	—	—	211	137	—	—	1,314	1,122	135	1,420	91	235

Table 5.1 (cont.)

	Patents Granted to Nationals				Patents Granted to Foreigners				Patents Granted to Nationals in Foreign Countries			
	1967	1971	1976	1980	1967	1971	1976	1980	1967	1971	1976	1980
Semi-industrialized Market Economies												
Rapid Growth												
Spain	2,758	2,042	2,000	1,485	6,827	7,764	7,500	7,739	627	933	766	1,180
Israel	178	202	200	305	935	1,225	1,200	1,419	219	231	146	316
Greece	975	1,227	1,343	1,114	2,302	698	1,285	942	61	70	81	691
Singapore	5	2	—	1	26	334	—	548	—	—	5	5
Portugal	84	214	46	95	1,045	3,238	1,319	2,200	53	57	50	50
Brazil	262	429	450	349	684	1,543	1,500	3,494	63	85	88	113
S. Korea	207	200	1,593	258	152	117	1,727	1,161	20	20	50	50
Slow to Moderate Growth												
Chile	80	58	60	60	1,237	1,115	514	514	—	—	—	—
Venezuela	41	237	50	55	954	1,599	514	408	—	—	—	—
Argentina	1,244	1,346	1,300	1,264	4,488	3,484	2,800	2,843	81	152	102	133
Mexico	1,981	412	300	174	7,922	5,199	3,000	1,831	149	148	181	171
Turkey	30	52	35	34	438	357	588	424	—	—	—	—
Uruguay	165	88	46	41	351	161	110	236	—	—	—	—

Developing Economies												
Ecuador	5	8	7	7	126	180	103	103	—	—	—	—
Iraq	22	5	12	14	146	67	150	24	—	—	—	—
Morocco	28	24	23	21	391	313	334	330	—	—	—	—
United Arab Republic (Egypt)	48	13	16	10	873	236	511	317	—	—	—	—
Colombia	49	62	30	36	851	651	600	808	—	—	—	—
Philippines	16	46	108	82	498	946	767	755	—	—	—	—
Kenya	0	1	5	—	104	121	98	97	—	—	—	—
India	428	661	433	500	3,343	3,256	2,062	2,000	72	70	73	57
Sri Lanka	1	10	4	5	4	148	156	36	—	—	—	—
African Intellectual Property Organization	1	15	3	26	573	455	545	545	—	—	—	—
Planned Economies												
E. Germany	11,520	8,295	3,755	4,455	8,351	9,854	2,735	1,371	976	2,240	1,652	992
Czechoslovakia	3,613	2,824	4,880	6,763	787	1,276	2,220	1,854	1,718	1,735	927	515
Soviet Union	24,008	33,534	40,259	92,897	662	2,098	1,883	7,852	1,379	2,973	3,309	2,601
Hungary	414	559	594	760	663	1,054	1,155	1,081	596	1,020	1,116	1,294
Poland	1,564	2,331	5,619	5,736	485	543	2,380	1,962	447	538	347	629
Bulgaria	423	674	750	1,271	90	240	393	102	78	164	167	242
Yugoslavia	173	143	58	58	650	706	355	355	95	90	87	110
Rumania	2,955	1,075	1,123	1,194	1,283	1,246	572	814	224	313	106	103

Source: *Industrial Property Statistical Report*, annual issues, World Intellectual Property Organization, Geneva.

The semi-industrialized nations have a varied experience in patenting. Most of the rapid-growth countries show expansion in patents granted to nationals (or have relatively high levels of patenting, e.g., Spain). The slower growing semi-industrialized countries in general have experienced some decline in national patenting. Patents granted to foreigners have tended to increase in the fast growing semi-industrialized countries and to decrease quite drastically in the slow-growth countries (for the group, patenting by foreigners was only 40 percent of its 1967 level in 1980). This decline reflects policy changes by this group of countries and other developing countries toward multinational firms. In general, through adminstrative procedures and through exclusion of certain technology areas from patentability (chiefly food and drugs), patenting by foreigners has been cut back. Unfortunately, as will be discussed later, these policies have not produced significant expansion in patenting by nationals.

The developing countries on the whole have relatively low levels of national patenting and high ratios of patenting by foreigners (policies in India have curtailed the latter). While data on patenting abroad are incomplete, available data for both semi-industrialized and developing countries indicate that the ratio of patenting abroad to patenting at home is much lower than is the case for industrialized countries.

The industrialized planned economies in general have relatively high levels of patenting by nationals and low levels of foreign patenting and patenting abroad. With the exception of East Germany and Rumania, the planned economies have expanded patenting activity over the period. This and the low levels of patenting by planned economy inventors in industrialized market economies suggests that patentability standards may differ considerably between industrialized market and planned economies.[6]

Table 5.2 provides a summary of data for nine countries operating utility model or petty patent systems. All of these countries are relatively successful in invention given their levels of development (Brazil introduced its utility model in 1970 and we have only recent data; Italy has not reported recent data). Petty patents are granted primarily to nationals (although West Germany has granted a significant number to foreigners from countries without petty patent systems). They are also granted primarily to individuals rather than to large corporate firms. Most are granted in mechanical technology rather than in chemical or biogentic technology.

member countries. This legal instrument will have important implications for future data interpretation but has had little impact on the data reported here. Proximity of markets is also a factor in patenting abroad—particularly in the case of Canada and the United States.

6. Table 5.4 indicates that a considerable part of patenting abroad by the planned economies is in other planned eonomies. The planned economies also have ratios of patents granted to scientists and engineers comparable to those in industrialized market economies, see table 5.9.

Table 5.2 **Utility Models (Petty Patents) Granted 1967**

	Applications						Utility Models Granted					
	Nationals			Foreigners			Nationals			Foreigners		
	1967	1975	1980	1967	1975	1980	1967	1975	1980	1967	1975	1980
W. Germany	42,214	30,114	26,094	11,344	11,938	8,153	20,948	12,099	10,252	2,400	2,181	1,879
Italy	4,418	—	—	778	—	—	3,935	—	—	702	—	—
Japan	109,154	178,992	190,388	1,906	1,668	1,397	20,601	47,449	49,468	721	957	533
Philippines	141	565	762	2	7	24	94	331	465	—	9	3
Poland	1,647	1,896	2,523	22	31	36	411	1,775	1,680	4	25	20
Portugal	139	78	118	25	13	15	77	153	159	9	25	6
Spain	7,601	7,650	5,380	710	1,353	1,162	6,177	4,128	3,845	600	2,041	11,131
Brazil	—	—	1,657	—	—	89	—	—	131	—	—	13
S. Korea	—	7,052	7,936	—	238	622	—	1,032	1,315	—	14	438

Source: *Industrial Property Statistical Report*, annual issues, World Intellectual Property Organization, Geneva.

The advantage of the petty patent is that it broadens the invention base by providing incentives to encourage individuals and small firms to develop inventions. Some semi-industrial countries, notably South Korea and now Brazil, are using this legal system effectively. Japan and West Germany have used it effectively in the past.

Table 5.3 provides data for two weaker legal instruments: the industrial design patent and the trademark. In a sense, a design patent is a petty patent and may serve a similar purpose. Those countries with petty patent systems also have relatively active design patent systems. Design patents have generally not experienced the same pattern of decline observed in invention patents. Except for Canada and the smaller European countries, design patenting by foreigners is a relatively small fraction of total patenting. This is particularly true for semi-industrialized and developing countries where multinational firms have not utilized this instrument for protection (in contrast to the use of invention patents).

The data on trademarks, on the other hand, show that foreign firms are using trademark protection in most markets, including the semi-industrialized and developing countries. An expansion of trademark registration to nationals and foreigners is observed in the majority of economies of all types except the planned economies. This is consistent with the general pattern of industrial trade expansion.

5.2 Comparative Advantage Patterns

Table 5.1 provides data on patents granted to nationals at home, on patents granted to nationals abroad, and on patents granted to foreign inventors. The ratio of patents granted to nationals to total patents granted varied from a high of .76 in the planned economies (and the United States) to a low of .11 for all developing economies in the late 1960s (see table 5.9 for a summary). The ratio of patents granted to nationals to patents granted to nationals abroad ranged from over 2.0 for many developing countries to around .1 for developing and slow-growth semi-industrialized countries.

The first ratio is related to the level of development of the country in question and to its size and degree of economic integration with other countries (particularly for the European Economic Community members and Canada and the United States). It is relevant to this discussion, however, because it indexes technology trade between countries. A firm has an incentive to obtain patent protection in a second country either because it is exporting products protected by the patent to the second country, producing such products in the second country, or selling technology directly through a licensing or technical agreement. The cost of obtaining patents abroad will be a factor in the firm's decision to patent abroad as will the expected market for the protected invention.

Table 5.3 **Industrial Design Patents and Trademarks Granted (1975, 1980)**

	Industrial Designs Granted				Trademarks Granted			
	Nationals		Foreigners		Nationals		Foreigners	
	1975	1980	1975	1980	1975	1980	1975	1980
Industrialized Market Economies								
Moderate to Rapid Growth								
Japan	34,129	30,696	700	593	104,156	41,577	5,010	5,290
Austria	3,987	4,260	1,517	1,744	1,458	3,333	1,247	2,148
France	11,320	13,209	857	1,560	12,645	37,332	4,312	9,784
Denmark	390	314	486	630	1,520	1,324	3,704	3,339
W. Germany	54,231	70,701	2,609	4,844	9,396	13,006	3,432	3,838
Benelux	1,671	1,691	1,376	1,262	5,529	4,418	3,571	3,082
Norway	243	252	364	434	522	464	2,531	2,675
Slow Growth								
Canada	337	337	1,168	978	3,507	8,779	3,391	6,755
Ireland	34	46	176	284	107	162	893	2,098
Switzerland	465	351	213	325	2,552	2,462	1,508	1,507
Sweden	1,283	1,558	364	588	1,397	1,577	2,591	2,608
United States	3,428	3,056	854	892	28,353	17,319	2,578	1,566
Australia	1,165	1,377	568	580	2,835	1,860	4,252	2,715
United Kingdom	1,665	2,166	1,354	2,799	5,878	3,356	5,562	3,352
Finland	165	371	222	350	276	703	1,126	3,542
New Zealand	157	170	167	173	845	524	2,015	1,318

Table 5.3 (cont.)

	Industrial Designs Granted				Trademarks Granted			
	Nationals		Foreigners		Nationals		Foreigners	
	1975	1980	1975	1980	1975	1980	1975	1980
Semiindustrialized Market Economies								
Rapid Growth								
Spain	3,234	2,239	224	407	—	11,119	—	12,822
Israel	115	266	42	56	224	255	1,064	868
Greece	—	—	—	—	1,546	1,260	1,469	1,800
Singapore	—	—	—	—	—	784	—	2,499
Portugal	266	335	216	228	770	1,035	481	581
Brazil	—	136	—	81	—	136,808	—	42,821
S. Korea	1,583	3,917	6	154	—	—	—	—
Hong King	—	—	—	—	348	603	1,182	1,647
Slow to Moderate Growth								
Chile	—	—	—	—	2,883	1,986	2,810	1,735
Venezuela	59	77	34	16	635	2,360	1,452	1,961
Argentina	2,426	na	159	na	12,428	—	2,032	—
Costa Rica	—	—	—	—	521	—	974*	—
Mexico	—	—	—	—	3,352	8,637	3,117	8,292*
Turkey	—	—	—	—	557*	1,129**	1,171*	1,181**
Uruguay	—	—	—	—	1,293	6,414	1,152	541

Developing Economies								
Ecuador	—	—	—	—	210	513	612	1,077
Iraq	19	9	—	—	68	184	236	885
Morocco	82	116	15	40	428	541	309	443
United Arab Republic (Egypt)	127	166	8	27	234	145	396	408
Colombia	11	na	5	na	702	584**	1,542	672**
Philippines	151	na	19	na	539	1,225	341	1,013
Kenya	—	—	—	—	153	443	585	747
Ghana	—	—	—	—	27	8	263	167
India	723	na	29	na	3,019	na	640	na
Sri Lanka	8	na	—	na	43	160	130	376
Indonesia	—	—	—	—	1,160	6,479	697	2,741
Pakistan	74	93	14	36	283	494**	640	780**
Zambia	—	—	3	—	22	4	441	215
African Intellectual Property Organization	26	—	57	—	62	na	954	na
Planned Economies								
E. Germany	—	—	—	—	299	150	325	265
Czechoslovakia	577	1,304	8	20	182	134	302	258
Soviet Union	—	—	—	—	48	1,627	5	559
Hungary	165	120	11	28	107	149	290	194
Poland	139	124	16	28	288	116	640	544
Bulgaria	27	38	5	6	15	73	434	492
Yugoslavia	102	na	30	na	156	na	154	na
Rumania	—	—	—	—	205	418	334	53

Source: *Industrial Property Statistical Report*, annual issues, World Intellectual Property Organization, Geneva.

*1976.

**1979.

The ratio of patents granted to nationals to total patents has risen in most rapidly growing economies and declined in most slow growing economies. For example, in the United States the ratio fell from .78 in 1967 to .60 in 1980. In Japan it rose from .66 to .82 over the same period. This can be taken as an index of changing comparative advantage. Table 5.4 presents patent (trade) "balance" data for 1967 and 1980. These data are organized to present the persepective of the granting country (i.e., row proportions sum to one). These data show that the great bulk of foreign patents granted in all countries, whether industrial, semi-industrial, developing, or planned, originate in industrial countries. Even the

Table 5.4 Patent Balance Data, 1967 and 1980: Perspective of Granting Country

Granting Country	Patents Granted to Foreigners		Percent Originating in: United States		United Kingdom		Germany	
	1967	1980	1967	1980	1967	1980	1967	1980
Industrial								
Japan	6,896	8,074	.49	.49	.09	.06	.16	.05
Austria	3,920	4,481	.21	.13	.07	.04	.09	.46
France	31,749	19.622	.34	.28	.11	.07	.24	.26
Denmark	1,997	1,453	.23	.22	.11	.09	.22	.23
W. Germany	8,300	10,362	.41	.31	.12	.06	—	—
Belgium	na	5,081	na	.32	na	.04	na	.17
Norway	1,817	1,843	.26	.23	.11	.08	.19	.15
Netherlands	1,913	2,907	.31	.30	.10	.05	.22	.21
Canada	24,753	22,392	.55	.60	—	.05	.28	.08
Italy	na	6,190	na	.01	na	.01	na	.29
Ireland	635	1,407	.29	.32	.24	.17	.11	.16
Switzerland	16,462	4,486	.22	.22	.08	.05	.38	.32
Sweden	7,532	3,604	.32	.29	.10	.06	.25	.22
United States	14,378	24,675	—	—	.19	.09	.26	.14
United Kingdom	28,893	18,646	.47	.36	—	—	.24	.21
Finland	739	1,464	.20	.18	.05	.07	.17	.20
Semi-industrial								
Spain	6,827	7,739	.27	.25	.08	.07	.17	.20
Israel	935	1,419	.39	.46	.10	.09	.13	.16
Greece	1,319	942	.29	.21	.06	.08	.12	.22
Portugal	1,038	2,200	.18	.23	.11	.08	.19	.17
S. Korea	152	1,446	.45	.26	.02	.04	.28	.08
Brazil	679	6,228	.42	.36	.08	.04	.13	.22
Chile	1,224	na	.46	na	.07	na	.12	na
Venezuela	961	408	.59	.47	.04	.04	.05	.11
Argentina	4,479	na	.50	na	.08	na	.08	na
Mexico	5,817	2,389	.44	.62	—	.03	.05	.02
Turkey	427	—	.29	—	.12	—	.21	—
Uruguay	350	236	.41	.24	.08	.12	.13	.13

Eastern European planned economies grant the bulk of their foreign patents to Western European inventors.

The dominance of industrial countries in origination of patents granted abroad reflects their general comparative advantage in invention. The ratio of patents granted to nationals abroad to patents granted to nationals at home is a rough index of the degree of "pioneeringness" or "adaptiveness" of invention. This index is affected by size of country and proximity of similar countries (as in the EEC) and thus is not ideal. It varies so markedly between industrial countries (around 2) and semi-industrial countries (.15–.25) and developing countries (.1) that no rea-

Percent Originating in									
Japan		Other Industrial		Planned		Semi-industrial		Developing	
1967	1980	1967	1980	1967	1980	1967	1980	1967	1980
—	—	.25	.31	.01	.04	—	.002	—	—
.02	.04	.66	.27	.09	.05	—	.02	.01	.002
.04	.10	.21	.21	.05	.05	.01	.03	—	.001
.02	.06	.39	.37	.02	.03	.01	.08	—	.002
.04	.23	.37	.32	.05	.05	.01	.03	—	.001
na	.06	na	.38	na	.03	na	.03	na	.001
.02	.05	.50	.47	.005	.02	.005	.004	.006	.001
.02	.15	.32	.26	.02	.02	—	—	.01	.006
.08	.09	.03	.15	.04	.01	.012	.02	.008	.001
na	—	na	.55	na	.05	na	.09	na	.005
.01	.01	.33	.32	—	—	.01	.02	.005	.005
.02	.09	.27	.27	.02	.04	.01	.006	—	.001
.01	.07	.28	.32	.03	.04	—	.003	.01	.001
.10	.25	.40	.53	.02	.03	.02	.02	.01	.001
.07	.12	.16	.28	.01	.01	.04	.02	.01	—
.01	.04	.53	.39	.03	.09	.005	.02	.003	.01
.01	.05	.45	.40	.01	.02	.004	.007	.01	.001
.01	.02	.35	.26	.01	.01	.01	.001	.001	.001
.02	.03	.46	.38	.03	.05	.02	.02	.001	.01
.01	.03	.45	.42	.005	.01	.05	.05	.01	.01
—	.50	.24	.09	—	.02	—	.002	.007	.01
.01	.06	.32	.30	.001	.01	.03	.01	.01	.001
.03	na	.26	na	.01	na	.04	na	.007	—
.03	.03	.28	.23	—	.01	.01	.09	.001	.02
.01	na	.31	na	.005	na	.01	na	.008	—
.10	.03	.31	.26	.06	.01	.04	.02	—	.07
.002	—	.33	—	.04	—	.007	—	—	—
.02	.02	.22	.31	.01	.01	.12	.15	.009	.01

Table 5.4 (cont.)

Granting Country	Patents Granted to Foreigners 1967	Patents Granted to Foreigners 1980	Percent Originating in: United States 1967	United States 1980	United Kingdom 1967	United Kingdom 1980	Germany 1967	Germany 1980
Developing								
Ecuador	126	103	.41	.56	.04	.01	.21	.04
Iraq	161	24	.34	.08	.10	.20	.17	.20
Morocco	387	330	.21	.22	.04	.03	.10	.12
U.A.R. (Egypt)	867	317	.27	.31	.06	.07	.14	.19
Colombia	848	808	.57	.58	.08	.04	.10	.05
Philippines	496	775	.67	.54	.05	.03	.03	.08
Kenya	104	97	.24	.28	.40	.21	.05	.14
India	3,329	na	.33	na	.24	na	.11	na
Sri Lanka	53	174	.21	.42	.15	.17	.06	.08
O.A.P.I.	513	136	.12	.10	.03	.06	.06	.61
Planned								
E. Germany	1,553	1,371	.03	.20	.09	.04	.40	.27
Czechoslovakia	787	1,546	.05	.18	.05	.07	.17	.27
Soviet Union	503	1,572	.07	.22	.17	.05	.17	.20
Hungary	512	1,018	.06	.17	.08	.06	.18	.26
Poland	484	1,962	.07	.22	.08	.07	.14	.03
Bulgaria	166	425	.03	.06	.02	.08	.28	.29
Yugoslavia	644	na	.07	na	.07	na	.18	na
Rumania	1,283	814	.06	.24	.06	.04	.21	.24

Patents Originating Summary

	Patents Granted 1967	Patents Granted 1980	Patents Originated 1967	Patents Originated 1980
Industrial	149,994	146,714	181,243	172,651
Semi-industrial	24,208	23,716	1,796	1,913
Developing	6,884	6,221	805	750
Planned	5,932	8,708	6,225	6,426

Source: *Industrial Property Statistical Report*, annual issues, World Intellectual Property Organization, Geneva.

sonable adjustment for these factors would alter the picture. Invention in developing countries is almost entirely adaptive in nature. Some of the more advanced semi-industrial economies (Spain, Israel, Brazil) appear to have significant pioneering invention, but they are still predominantly adaptive. The data from the planned economies are more difficult to interpret as they may be subject to considerable domestic policy effects.

The overall picture that emerges from these data supports both the notion of technology trade based on the differentiation of invention along a pioneering-adaptive continuum. Developing and semi-industrialized

Percent Originating in									
Japan		Other Industrial		Planned		Semi-industrial		Developing	
1967	1980	1967	1980	1967	1980	1967	1980	1967	1980
—	.05	.31	.28	—	—	.02	.04	.008	.02
.06	—	.23	.44	.09	.08	.006	—	.006	—
.003	.01	.57	.52	.03	.03	.04	.04	.003	.03
.018	.05	.32	.32	.19	.02	.01	.04	.002	.003
.01	.02	.21	.26	.006	.01	.02	.03	.006	.01
.09	.12	.15	.18	—	.02	.002	.02	.008	.01
.02	.01	.26	.35	—	.01	—	—	.03	—
.04	na	.22	—	.05	na	.008	na	.004	—
.02	.04	.54	.25	.02	.02	—	.01	—	.01
.002	—	.78	.20	—	.01	.004	.02	.004	—
.01	.02	.32	.23	.13	.22	.003	.02	.02	.002
.01	.07	.35	.10	.37	.28	.005	.03	—	—
.07	.10	.48	.30	.04	.13	.004	.002	—	.001
.01	.04	.42	.21	.24	.24	.004	.02	.01	.003
.004	.03	.35	.51	.35	.14	.004	.001	.002	—
.02	.02	.45	.19	.19	.36	.006	.002	.006	—
.02	na	.46	na	.20	na	—	na	—	na
.02	.02	.39	.29	.25	.16	.01	.01	.005	.005

countries are overwhelmingly importers of technology and they specialize in adaptive invention at home. The jockeying for position among industrialized-country exporters has changed somewhat in the past four years with Japan moving into a strong competitive position. The U.S. share of patent exports fell from .37 in 1967 to .30 in 1979. Japan's share rose from .03 to .11.

The notion that developing countries engage in mostly adaptive invention suggests that inventions made in more highly developed countries "disclose" possibilities for modifications of these inventions in the "downstream" developing countries. Clearly their invention is different in character than that of developed countries. It is apparently of low value "upstream" in industrialized, developed countries with high wages. Since these countries do obtain some patents abroad it will be useful to look at the patterns of this invention.

Table 5.5 provides data organized from the perspective of the originating country for 1980. Predictably, most patenting abroad originates in developed countries. This is where the large markets are. Argentina, Brazil, and Mexico, however, do appear to be patenting "downstream" in developing Latin American countries to a significant extent. This

Table 5.5 **Patent Balance Data, 1980: Perspective of Originating Country**

Origin Country (Patents Originated)		Percent Granted in: United States	Japan	Germany	Other Industrial	Planned
Japan	(20,663)	.35	—	.11	.422	.022
Austria	(1,669)	.158	.022	.015	.70	.013
France	(12,511)	.167	.035	.073	.479	.055
Denmark	(1,103)	.148	.027	.061	.63	.057
W. Germany	(33,708)	.171	.040	—	.584	.006
Belgium	(1,720)	.144	.028	.038	.604	.039
Norway	(549)	.144	.044	.064	.562	.086
Netherlands	(5,964)	.109	.059	.090	.571	.031
Canada	(2,200)	.503	.036	.037	.326	.015
Italy	(5,877)	.137	.025	.052	.506	.061
Ireland	(107)	.206	.009	.047	.599	—
Switzerland	(9,827)	.127	.041	.096	.50	.059
Sweden	(4,769)	.173	.042	.058	.594	.044
United States	(54,360)	—	.073	.059	.678	.033
United Kingdom	(11,140)	.219	.041	.054	.478	.045
Finland	(928)	.133	.022	.033	.599	.100
Spain	(1,180)	.028	.006	.009	.85	.007
Israel	(316)	.377	—	.044	.474	—
Greece	(691)	.006	—	.003	.986	.003
Brazil	(113)	.204	.018	.009	.397	.009
Argentina	(133)	.211	.015	.008	.187	.015
Mexico	(171)	.275	.029	.018	.326	.029
India	(57)	.175	.053	.018	.489	.018
Panama	(233)	.009	—	.021	.562	.069
Bahamas	(103)	.058	—	.049	.524	.058

provides some support for the adaptiveness hypothesis, but a full treatment would require detailed industry data.[7]

Data on receipt of royalties and fees to U.S. residents for the use of intangible property such as patents, techniques, process designs, trademarks, and other technology-related activities show that the export of technology is not a trivial activity. Total receipts of royalties and fees were $5.5 billion in 1978.[8] Product trade data also show that exports of R & D intensive products have been important to the U.S. economy. In 1964 the trade balance in R & D intensive manufactured products showed

7. Such data are now becoming available from the International Patent Documentation Center (INPADOC 1981). Patents can be classified by International Patent Class (IPC). A concordance between IPC and Standard Industrial Classes (SIC) has been made by INPADOC. F. M. Sherer (this volume) has questioned the value of such concordances, but for reasonably broad industrial classes they may be adequate.

8. See table 5.8 for data from several OECD countries on receipts and payments of royalties and fees.

Percent Granted in							
Semi-industrial				Developing			
Latin America	Africa	Asia	Europe	Latin America	Africa	Asia
.021	—	.05	.022	.001	.001	.001
.022	—	.017	.033	.002	.015	.003
.016	—	.016	.128	.002	.023	.006
.014	—	.012	.044	.001	.006	—
.049	—	.014	.064	.002	.005	.005
.024	—	.020	.075	.005	.015	.008
.024	—	.016	.056	—	.004	—
.045	—	.008	.078	.002	.003	.004
.033	—	.012	.022	.009	.006	.001
.066	—	.015	.118	.003	.011	.006
.065	—	.019	.037	.009	—	.009
.044	—	.030	.080	.003	.013	.007
.030	—	.006	.048	.0002	.004	.001
.066	—	.027	.048	.005	.007	.004
.027	—	.038	.074	.003	.013	.008
.055	—	.002	.044	.009	.001	.002
.042	—	.003	.039	.006	.008	.002
.070	—	.003	.032	—	—	—
.001	—	—	.001	—	—	—
.150	—	—	.186	.009	.009	.009
.406	—	—	.090	.068	—	—
.088	—	.006	.053	.123	.006	.047
.053	—	—	.123	—	.053	.018
.039	—	.034	.150	.004	.026	.086
.039	—	.029	.126	.049	.049	.019

net exports of $8.8 billion and net imports of $3.7 billion in non-R & D intensive manufactured products. In 1979 net exports of R & D intensive manufactured products had grown to $39.3 billion, but net imports of non-R & D intensive products had grown to $34.8 billion. (These data do not include agricultural and mineral products, also important in trade.)

5.3 Evidence of Declining Patent/Inventive Input Ratios

I now turn to four data sets on patents and inventive inputs (scientists and engineers engaged in R & D and R & D spending) to examine the question of "inventor productivity." All four data sets show that the ratio of patents granted per unit of inventive input has fallen from 1964 to 1979–80. This decline shows up for almost all of the industries in the two data sets (United States and Japan) where industry-specific data are available. The decline shows up in each of the five countries for which

OECD data are available (United States, United Kingdom, France, West Germany, and Japan), and it shows up in most of the forty-four countries for which UNESCO data are available.

A decline in the ratio of patents granted to inventive inputs need not imply that *real* invention per unit of inventive input has declined. A change in the "propensity to patent" (i.e., patents granted per unit of real invention) could have produced the results reported here. A rise in the cost of obtaining and enforcing patents, changes in legal systems, and changes in company policies could produce changes in the propensity to patent. We know that some changes have occurred particularly because of rising patent enforcement costs. A few countries have changed their legal systems as well. However, many countries have not experienced rises in patent enforcement costs and have actively encouraged invention through subsidies and favorable tax treatment. Changes in the propensity to patent are unlikely to explain the universal decline in patenting per inventive input unit shown by the data.[9]

Consider first the data by industry for the United States. Table 5.6 provides the most detailed industry data readily available on patents granted to nationals and foreigners, R & D expenditures (in 1972 constant dollars), and scientists and engineers engaged in R & D. Data on the proportion funded by government and on the proportion considered "basic" and "development" are also provided by the National Science Foundation.

Table 5.6 shows that R & D spending per scientist and engineer, while varying somewhat by industry, has changed little from 1964 to 1978. It increased at an annual rate of only .0047. Patenting per scientist and engineer fell at an annual rate of −.0126 from 1964–66 to 1971–72 and −.0439 from 1971–72 to 1976–78 (−.0283 over the entire period.) Regression (1) provides a statistical description of this decline, controlling for industry effects. The annual rates are unchanged by the correction for industry effects, and the decline from 1964–66 to 1976–78 is highly significant from a statistical perspective. (These data do not include patenting for 1979 and 1980.) At the national level, patents granted to national inventors declined by 10.2 percent from 1976–78 to 1980 (this excludes the extraordinarily low patenting in 1979). Numbers of scientists and engineers and R & D expenditures rose by roughly 10 percent during this period. (In table 5.6, R & D and scientists and engineers data are lagged behind patents granted by two years).

Since R & D spending rose relative to scientists and engineers only slightly, patents granted per dollar spent on R & D declined only slightly more than is the case for scientists and engineers. The table also shows that the ratio of national to foreign patenting fell in every industry in both

9. The data utilized in table 5.6 are summarized in National Science Board (1981).

periods. The change in this ratio is positively correlated with the change in labor productivity across industries over the 1966–78 period ($r = .583$). There is also a positive correlation between the change in the national to foreign patent ratio and the change in national patenting per scientist and engineer (.346 over the entire period; .556 in the second half). Changes in national patenting and foreign patenting are positively correlated for the 1966–78 period ($r = .701$), but changes in national patenting in the second half of the period are negatively correlated with changes in foreign patenting in the first period ($r = -.631$). The converse is also true ($r = .342$).[10]

Regressions (2) and (3) in table 5.6 report a simple effort to control for some characteristics of the research system on patenting per unit of inventive input. They provide some evidence that government funding increases inventive output while emphasis on basic research decreases it.

Our second set of data reported in table 5.7 includes industry level data for Japan. These data show that patent applications per scientist and engineer were lower in 1975–76 than in 1967–68 in all industries except textiles and foods, where they were unchanged. Patent applications per dollar expended on R & D also declined because R & D per scientist rose. (R & D spending is expressed in millions of 1970 constant yen.) A positive correlation between the changes in patents per scientists and engineers by industry between the United States and Japan exists with the transport (motor vehicles) and nonelectric machinery industries in both countries experiencing the largest declines.

Table 5.8 reports our third data set. These data were collected by the OECD and are somewhat more reliable than the fourth data set collected by UNESCO (summarized in table 5.9). The five countries included in the table undertake the bulk of the world's R & D. The decline in patents granted to national inventors per scientist and engineer (the scientist and engineer and R & D data are lagged two years prior to the patenting data, i.e., for the 1967 column S & E and R & D data are for 1965) shows up in each country. In the cases of Japan and Germany, patents per scientist and engineer peaked in 1971. In the United States, United Kingdom, and France, this ratio has declined since 1967. In terms of the date of investment in R & D, these declines set in two years earlier. The decline was therefore not directly associated with the energy price increases of the early 1970s.[11]

10. Some variation in patents granted is from changes in the "backlog" of patents applied for but not examined. A decline in patents granted in period T due to an increase in the backlog will produce an increase in patents granted in a later period. In the U.S. Patent Office, 1979 was a particularly bad year in this regard, and patenting was low because of an increase in the backlog. The 1979 data for the United States, United Kingdom, and France are not used in any of the calculations made in this paper because of this problem.

11. The data on R & D and Industrial Product (IDP) have first been converted to 1971 constant currency using national GDP deflators. They were then converted to U.S. dollars

Table 5.6 Industry Patenting (National and Foreign), R & D Expenditures, and Scientists and Engineers, United States, 1964–78

Industry	Ratios 1976–78			Annual Percent Changes 1964–66 to 1971–72				Annual Percent Changes 1971–72 to 1976–78			
	R & D / S & E	PN / S & E	PN / PF	PN / S & E	PN / R & D	R & D / S & E	PN / PF	PN / S & E	PN / R & D	R & D / S & E	PN / PF
Food	40.2	86.3	2.10	.057	.034	.023	−.065	−.039	.039	.001	−.027
Textiles	33.7	241.1	1.35	.021	.036	−.015	−.084	−.014	−.094	.040	−.066
All chemicals	50.3	159.1	1.38	−.018	−.016	−.002	−.068	−.030	−.038	.008	−.047
Industrial chemicals	56.9	173.1	1.35	.017	.014	.002	−.055	−.031	−.081	.011	−.039
Drugs	47.1	71.0	1.06	−.093	−.078	−.016	−.034	.010	.005	.005	−.057
Petroleum products	69.2	84.2	4.14	−.031	−.099	−.010	−.036	−.007	−.036	.033	−.070
Rubber products	42.7	276.7	1.89	−.029	−.072	.043	−.098	−.006	−.081	−.020	−.054
Stone and glass	42.5	214.2	1.84	−.018	.001	−.019	−.123	−.076	−.078	.002	−.054
Primary metals	46.2	55.7	1.11	−.040	−.009	−.030	−.088	−.089	−.094	.005	−.061
Fabricated metals	37.9	766.2	2.17	−.002	−.049	.038	−.086	−.064	−.063	−.002	−.046
Nonelectric machines	49.9	206.5	1.54	−.074	−.108	−.015	−.077	−.100	−.110	.010	−.057

Electric machines	52.2	100.1	1.78	.009	.002	.006	−.082	−.046	−.051	.005	−.062
Motor vehicles	79.4	95.5	1.91	−.029	−.021	−.005	−.061	−.034	−.060	.025	−.025
Aircraft	66.6	13.0	1.21	.041	.054	−.013	−.061	.023	.021	.003	−.062
Scientific and professional instruments	52.4	253.2	1.67	.001	−.030	.029	−.094	−.097	−.048	−.007	−.056
All industries	51.2	186.4	1.77	−.0126	−.0138	.0011	−.0742	−.0439	−.0529	.0082	−.0523

Regressions:

(1) $\text{LN(PN/S \& E)} = 5.0986 + \text{ind. dummies} - \underset{(.105)}{.0756}\, T2 - \underset{(.105)}{.3392}\, T3$ ($R^2 = .947$; $F = 38.27$).

(2) $\text{LN(PN)} = 5.0147 + \underset{(.166)}{1.18}\, \text{LN(S \& E)} + \underset{(1.058)}{2.526}\, \text{proportion govt. funded} - \underset{(10.97)}{13.91}\, \text{proportion basic}$
$+ \underset{(.98)}{1.419}\, \text{proportion development} + \text{ind. dummies} - \underset{(.106)}{.132}\, T2 - \underset{(.130)}{.433}\, T3$ ($R^2 = .97$; $F = .512$).

(3) $\text{LN(PN)} = .107 + \underset{(.15)}{1.23}\, \text{LN(R \& D)} + \underset{(1.00)}{1.93}\, \text{proportion govt. funded} - \underset{(10.15)}{13.77}\, \text{proportion basic}$
$+ \underset{(.55)}{1.38}\, \text{proportion development} + \text{ind. dummies} - \underset{(.099)}{.155}\, T2 - \underset{(.126)}{.526}\, T3$.

Source: *Science Indicators 1980*.

Note:
$T2$ = 1 if year equals 1971.
$T3$ = 1 if year equals 1978.
Standard errors in parentheses.

Table 5.7 **Patent Applications, Scientists and Engineers, and R & D Expenditures in Japan, 1967–76**

	Patents/S & E			Patents/R & D			R & D/S & E		
Industry	1967–68	1971–72	1975–76	1967–68	1971–72	1975–76	1967–68	1971–72	1975–76
Chemicals	1.60	1.30	1.42	.425	.187	.218	3,762	6,969	6,528
Nonelectrical machinery	3.28	2.66	2.33	.948	.422	.273	2,914	11,402	4,714
Electrical machinery	1.23	.93	1.12	.378	.132	.197	3,251	7,042	5,667
Transport and construction equipment	2.08	1.49	1.32	.328	.136	.110	6,332	10,959	11,832
Textile and household goods	4.82	5.54	4.89	1.413	1.071	.988	3,412	5,169	4,954
Foods	1.37	.84	1.38	.494	.169	.270	2,778	4,949	5,108
All industries	1.80	1.43	1.54	.733	.200	.236	3,610	7,150	6,540

Source: *Statistical Yearbook of Japan*, Ministry of Trade and Industry, Tokyo.

Table 5.8 **OECD Data: Patents, R & D, and Scientists and Engineers**

	Patents to Nationals (PN)	Scientists and Engineers (S & E)	PN / S & E	PN / R & D	R & D / IDP	Royalties and Fees: Received	Royalties and Fees: Paid	Royalties and Fees: Received / PN	Royalties and Fees: Paid / PF
United States									
1967	51,274	494.5	103.8	2.85	2.49	23.84	2.28	.32	.16
1971	55,988	555.2	100.8	3.145	2.12	31.91	3.02	.36	.14
1975	44,162	525.1	84.1	2.484	1.98	28.96	3.19	.32	.12
1980	37,652	573.9	65.6	2.341	1.91	26.89	2.55	.49	.14
United Kingdom									
1967	9,807	49.9	196.5	7.36	2.00	2.51	2.38	.14	.08
1971	10,376	52.8	196.5	8.45	1.85	3.61	3.28	.17	.11
1975	8,855	80.7	109.7	8.75	1.75	3.32	2.73	.24	.09
1980	5,158	80.7	63.8	5.23	1.82	na	na	na	na
West Germany									
1967	5,126	61.0	84.0	2.30	1.28	1.24	2.64	.03	.31
1971	8,295	74.9	110.7	2.23	1.54	1.53	3.94	.04	.40
1975	10,395	102.5	101.4	2.69	1.59	1.73	3.85	.05	.36
1980	9,826	111.0	88.5	2.29	1.64	1.91	4.64	.06	.40
France									
1967	15,246	42.8	356.2	10.44	1.42	2.68	3.16	.19	.10
1971	13,696	57.2	239.4	7.90	1.29	4.42	4.59	.26	.12
1975	8,420	64.1	131.4	4.07	1.39	6.54	5.44	.51	.25
1980	8,433	68.0	124.0	3.61	1.35	9.19	7.42	.73	.42
Japan									
1967	13,877	117.6	118.0	9.67	.84	.37	3.28	.06	.47
1971	24,795	157.1	157.8	7.70	1.11	.75	6.12	.05	.52
1975	32,465	238.2	136.3	8.49	1.19	1.01	4.79	.05	.63
1980	38,032	272.0	139.8	8.50	1.29	1.33	5.85	.07	.63

Source: *Science Indicators 1980*.

The data on the ratio of expenditures on R & D to industrial product show this ratio to be declining sharply in the United States and rising significantly in Japan and West Germany. In 1980 these five countries did not differ greatly on this measure.

We also have data on royalties and fees paid and received for these five countries (expressed in "real" U.S. dollars as was R & D). The ratios of royalties and fees received per patent granted to nationals abroad are relatively low for West Germany and Japan, while the reverse is true for the ratio of payments made per patent granted to foreigners. These two countries are "aggressive" about expanding their R & D investments and patenting in foreign countries. Their strategy has generally been to borrow or import technology to build their own capacity. This is reflected in the fact that they pay substantial fees for imported technology and receive relatively low payments for their patenting abroad (although it should be noted that the payments data are for patents granted in prior years and do not match up with the patents data in the table.)[12]

Table 5.9 provides a summary of international data for forty-four countries (see table 5.1 for classification by region). Rows (1)–(5) provide means of the patent and trademark data reported in tables 5.1 and 5.3 by region. These means highlight the major features of the patent data. They show the decline in the importance of the United States in world patenting and the rise in importance of Japan, West Germany, and the planned economies. They also show the marked differences in patents granted abroad to patents granted at home—a measure of adaptiveness of invention—between the industrialized nations and the semi-industrialized and developing economies. They further show the high degree of foreign patenting in most of the world's economies.

Rows (6)–(9) provide data on ratios of patenting to numbers of scientists and engineers in the productive sector and on patenting to R & D expenditures in the productive sector. It should be noted that both the S & E data and the R & D data are subject to considerable errors. The UNESCO data provide a breakdown of both for the "productive" (i.e., industry, transport, commerce), education, and service sectors. I have used the data from the productive sector. A further problem with these data is that they are not available for all years and some interpolation was

using the purchasing power parity exchange rate of Kravis, Summers, and Heston (1980). This exchange rate is designed to enable better comparability of incomes between countries. The real costs of undertaking research may not be closely related to the real costs of producing goods generally. We do not have an ideal deflator for R & D spending in any single country and obviously no ideal deflator exists to achieve cross-country comparability. This paper does not attempt to draw strong conclusions from cross-country comparisons as a consequence. They are reported as a matter of convenience (but see note 12).

12. This inference requires comparability in the real dollar conversions. While expressing skepticism about conversion rates (see note 11), one can probably say that the problems are less serious for this group of countries than for most others.

required.[13] The most serious problem, however, is the exchange rate conversion. This conversion is relevant only if one wishes to make cross-section comparisons. Comparisons over time require only an appropriate deflator to convert expenditures to a constant currency unit. Row (8) provides R & D data in constant 1972 U.S. dollars where standard exchange rate conversions to dollars were made and where the U.S. deflator was used. Row (7) utilizes the purchasing power parity exchange rates developed by Kravis, Summers, and Heston (1980). This deflator modifies both the time series and cross-section aspect of the conversion and, while imperfect for the task at hand, is probably the best available.

Examination of the data in row (6) shows that patents per scientist and engineer have declined in the industrialized and slow growing semi-industrialized countries (which account for most of the world's patents—see row [1]). The numbers in parentheses are regression estimates of the decline in the ratios within countries (i.e., country dummies were included in the regressions). Statistically significant declines are shown for the last two periods relative to the first for these groups. In addition, virtually all individual countries in each group showed declines in the ratios. These ratios do vary considerably by type of economy, with the semi-industrialized countries (notably those with rapid growth) showing ratios far above the industrialized country standard. Developing countries are generally far below the industrialized countries in this regard.

In developing countries a relatively high proportion of time is devoted to adaptive invention, much of which is not patentable. Many of these countries have vented frustration over the terms on which technology is purchased in international forums. Few have shown imagination in developing legal systems suited to their competitive position in international invention. Most invention from these countries is adaptive. Yet they have generally not modified their patent systems to encourage adaptive invention. They have instead opted to weaken the scope of patent coverage in an attempt to discourage foreign patenting. In this the slow-growth industrialized economies and the developing economies have been successful. Unfortunately, they have also discouraged national invention in the process.

The data on patents per dollar expended on R & D are somewhat less regular in showing declines in patenting per unit of inventive activity than are the data on patents per scientist and engineer. Part of this is because of the problem of deflating these data appropriately. The data show

13. UNESCO statistical yearbooks provide data for available years and it is not possible to match up the data for all relevant years. Simple interpolation was used to fill in missing years. The classification of R & D and S & E data by type of performing organization is also subject to some differences between countries. Personnel data are classified as scientists and engineers, technicians, and other personnel. The inclusion of technicians in the data reported in table 5.9 would not have altered the results.

Table 5.9 International Data: Patenting and Invention Input Means by Region and by Period

	Industrialized Economies			Semi-industrialized Economies			
	Rapid Growth	USA	Other	Rapid–Moderate	Slow Growth	Developing Economies	Planned Economies
(1) Share of world's invention patents							
1967–71	.251	.316	.110	.026	.017	.004	.277
1976–79	.310	.233	.075	.033	.010	.004	.336
(2) Share of world's design patents							
1975–80	.852	.025	.041	.046	.017	.010	.029
(3) Share of world's trademarks							
1975–80	.412	.080	.064	.309	.092	.036	.007
(4) Ratio: patents granted to nationals abroad to patents (N)							
1967–71	1.94	1.51	2.28	.28	.092	.10	.155
1976–79	1.31	1.69	2.65	.20	.165	.09	.109
(5) Ratio: patents (N) to total patents							
1967–71	.39	.75	.19	.25	.17	.11	.76
1976–79	.51	.62	.18	.27	.20	.12	.84
(6) Patents per scientist and engineer (PN/S & E)[c]							
1967	.238	.248		.998	.380	.053	.269
1971	.258 (.08)	.214 (−.11)		.876 (.12)	.337 (−.02)	.066 (.08)	.218 (−.07)
1976	.201 (−.14)*	.152 (−.36)**		.494 (−.12)	.185 (−.69)**	.055 (.13)	.187 (.28)*
1979	.200 (−.09)	.108 (−.69)**		.550 (.05)	.154 (−.98)**	.052 (.02)	.243 (−.08)

(7) Patents per dollar expended R & D (PN/R & D)[a,b,c]						
1967–71	1.007	1.660	4.054	3.429	.340	1.092
1975–79	1.276	1.463	6.803	2.181	.337	1.297
(8) Patents per dollar expended R & D (PN/R & D)[a,c]						
1967–71	1.276	1.775	6.799	6.858	.777	1.092
1975–79	1.119	1.202	9.733	3.621	.822	1.297
(9) R & D/GDP[a,c]						
1967	.0325	.0230	.0094	.0040	.0056	.0357
1971	.0227 (−.38)**	.0168 (−.29)**	.0056 (−.53)**	.0043 (.13)	.0053 (−.05)	.0261 (−.26)**
1976	.0206 (−.48)**	.0159 (−.36)**	.0043 (−.77)**	.0041 (−.16)	.0041 (−.26)**	.0337 (−.08)*
1979	.0196 (−.52)**	.0171 (−.30)**	.0043 (−.78)**	.0041 (−.16)	.0039 (−.27)**	.0329 (−.11)*
(10) Regression of LN(R & D) on:[c]						
LN(MFG)	1.032**	1.25**	.627*	−.124	.301*	.767*
Industrial growth	−.0025	−.040	−.014	−.133*	.050**	.035
Trade intensity	2.722**	−1.46*	.55	−3.36*	−1.45*	—
R^2	.99	.99	.98	.96	.97	.99
F	238	769	61	25	55	160

Source: UNESCO Yearbooks.

Note: On time dummy variables. Country and time dummies included in regressions. Numbers in parentheses are coefficients.

*Coefficient > 1.5 times standard error.

**Coefficient > 2 times standard error.

[a]Numbers in parentheses are time dummy coefficients in a regression LN( ) on country and time dummies.

[b]These R & D data are deflated by the Kravis, Summers, and Heston (1980) purchasing power parity exchange rate.

[c]U.S. and other industrialized countries are combined.

general declines in patenting per dollar expended in R & D except in the rapidly growing semi-industrialized economies, in the planned economies, and for the data deflated by the purchasing power parity exchange rate for the rapidly growing industrialized economies.[14]

Row (9) of the table corroborates the pattern observed in the OECD countries of a decline in the share of industrial product devoted to R & D. This share has declined in virtually all countries in the data set, including the planned economies. This is consistent with the proposition that invention has become more costly (i.e., that the probability of discovery has declined). The magnitude of this deline in investment is highly significant and has important policy implications for growth when considered along with the evidence for declining productivity of invention.

Table 5.9 also reports an investment regression for each of these regions that is more "descriptive" in nature than analytical. In each region the log of R & D is regressed on the log of industrial Gross Domestic Product (GDP), the industrial growth rate in the previous ten years, and the trade intensity of the country (i.e., the ratio of the value of trade to GDP). Country and time dummy variables are included to pick up constant country effects. These regressions, while not particularly remarkable given the data and the problem of international comparability, suggest that investment decisions are reasonably systematic. Except for the slow growing semi-industrialized economies (a rather mixed bag of countries), investment in R & D is related to industry size. There is little evidence that past industry growth affects investment decisions (although this might differ if we had detailed industry data). Openness to trade appears to have a positive effect on R & D spending in the fast growing economies and a negative effect in the slow growing economies. The interpretation of this result is not readily obvious since openness to trade and willingness to invest in R & D may be jointly determined by a set of political factors. It is tempting to suggest that aggressive growth strategies, as by Japan and West Germany, produce this positive correlation, while the reverse is true for those countries pursuing less aggressive growth policies. This type of data, however, is not really suited to test that proposition, and these regressions are accordingly presented here in a data table and labeled descriptive.[15]

To conclude that a significant decline in real productivity of invention has taken place does not require proof that the propensity to patent has not changed. The magnitude of the declines in patenting per scientist and

14. A simple regression: LN(PN/S & E) = *b*LN(R & D/S & E) plus country and time dummies was run for each country group. The *b* coefficient was positive in all cases and greater than its standard error in all but the slow growing industrialized countries. This indicates that R & D data are measuring real scientific resources rather than scientists' and engineers' time. The time dummy coefficients were similar to those reported in row (6).

15. The problem of shifts between industries is particularly problematic for such comparisons.

engineer and per unit of R & D in the OECD countries for which we have good data is large. Furthermore, these countries have reduced spending on R & D relative to the market for inventions by significant amounts, presumably in response to a decline in invention potential. Broad cycles in growth potential have marked our history before. The 1970s may well have been more normal in this regard than the 1950s and 1960s.

Our data force us to deal with broad aggregates. If we had more detailed data by technology field, we would probably find that even prior to 1965 many technology fields were exhibiting declines in invention potential. This was true in the 1970s as well. It is just that the declines are outweighing the increases. One need only look at detailed patenting data by subclass to note cycles. Patenting activity may be sporadic for a period, then increase to a peak, and then decline. Of the patent subclasses utilized in the U.S. Patent Office today, the majority are considered "dead art" (i.e., patenting activity has ceased).

The natural model underlying these data is a search model in which a pool of potential invention is determined by existing technical and scientific knowledge. The pool is depleted by inventive activity and recharged in various ways. Other related inventive activity can recharge pools through disclosure effects. More basic scientific and technical research can produce findings which recharge as well.[16]

5.4 Implications for Studies of Technology

Most studies of the economic determinants of R & D spending by firms or of the economic outcomes attendant to that spending have not taken trade effects into account. Many studies have implicitly, if not explicitly, supposed that firms do not have the option to purchase new technology directly, except in "embodied" form in capital goods. In addition, many studies presume that the probability of discovery from a firm's R & D is constant over significant periods of time. Most studies recognize that industry-specific effects may be present in this probability, but few make any attempt to take into account the degree of adaptability of the R & D and its dependence on discoveries made by other firms, including international firms.

The data summarized in this paper, as well as the evidence on "overseas R & D" undertaken by U.S. multinational firms, suggest that for many problems the international dimension cannot be easily set aside.[17] Many firms have international R & D strategies with laboratories located in different markets and economic environments. Virtually all R & D activities have some elements of adaptiveness, and the probability of

16. Kislev and Evenson (1975) apply a simple search model to R & D processes. Such models require some enrichment but may be a useful starting point for further study.
17. See the paper by Edwin Mansfield in this volume.

discovery will depend on other firms making closely related discoveries. Studies based on a sample of only large firms in one industry (or industries), such as many in this volume, do not provide a realistic picture of industry equilibria regarding R & D strategy. Even in these large firms the variation in R & D spending has been noted to be much higher than for normal factors of production.[18] Had the entire industry been sampled, we would find that some firms in some industries engage in practically no formal R & D. Yet they exist in competitive equilibrium with other firms engaging in significant levels of R & D.

International data show this pattern of high variation in formal spending on R & D across countries. They also show that the degree of adaptiveness of R & D is highly correlated with the level of R & D spending. A further piece of evidence suggesting that significant trade in technology takes place is that many patented inventions are granted to individuals either not associated with firms or associated with very small firms. This would not occur to a very significant degree if it were not possible to sell invented technology in forms disembodied from a product.

The patent system is often seen primarily as a means for a firm to prevent infringement on the technology it has discovered and is using in production. A well-functioning patent system has two further important aspects: First, patent systems enable the exchange of technology by providing the basis for legal transactions. Second, patent systems require an "enabling disclosure" which legal scholars regard to be of great importance. Removing invention from secrecy is considered the main social benefit offsetting the cost of the limited monopoly granted. (Economists tend to stress incentives for invention as the major benefits.) We observe that when patent systems are functioning efficiently (i.e., the cost of obtaining and enforcing patent production is low) it encourages technology trade. When patent systems are not efficient, technology trade becomes closely integrated with product trade.

For certain types of studies, the fact that technology can be purchased and sold, that R & D activities can vary in adaptiveness, and that R & D productivity may be influenced by other firms' discoveries requires that we develop better "price" data for technology. Alternative types of technology acquisition activities also must be better specified than at present. We should, for example, be measuring a firm's investment in pioneering R & D, adaptive R & D, licensing and royalty payments, search costs for new designs, etc., if we are to understand fully the firm's investment motives. We should define more meaningful price variables facing the firm. Technology embodied in capital goods (or technical services) supplied by other firms is available at a real price and is a

18. Pakes and Schankerman (this volume).

substitute for some types of R & D activity and is quite possibly complementary to highly adaptive R & D. Other technology can be licensed for a price. A firm's own technical capacity will affect the price it pays. The supply side of these technology markets changes with new discoveries. Obviously, defining proxies for these prices will require a good deal of imagination and probably a few good case studies. A few studies are already showing progress on this score, however.[19]

The issue of changing invention productivity is of obvious importance, independent of our interest in investigating firm behavior more clearly. If invention potential pools are being depleted more rapidly than they are being recharged, economic growth will suffer. If this depletion-recharge process differs significantly by industry and by economic environment, it has important implications for comparative advantage and incomes associated with it. The data reviewed in this paper are in many ways too aggregative to investigate adequately the depletion-recharge issue. They strongly suggest that the United States and a few other developed economies may have experienced a fairly broad scale net depletion of invention potential pools. Further, the international patterns of comparative advantage appear to have changed markedly in recent years. The two phenomena are related and their net effect on the U.S. economy in the past fifteen years may have been quite significant. It is not unreasonable to suppose that the *potential* economic growth of the economy (setting aside macropolicy issues) may well have been considerably lower since 1965 or so than in the preceding fifteen to twenty years. It is also not unreasonable to suppose that some loss of international comparative advantage rents has been sustained by the economy.

As economists investigate this issue, policy attention will focus on the recharge mechanism. Progress toward measuring the effectiveness of alternative recharge strategies (investment in scientific research, etc.), however, will depend on our ability to specify the depletion mechanisms (i.e., the invention process). Patent data are now becoming available in more detailed form (IPC classes) and for more countries.[20] They provide scope for both firm level and more aggregate trade-type studies. Application of trade theory to the issue should help sort out relevant issues.

A final point can be made regarding patent system policy. International organizations have pressed strongly for the establishment of international agreements on intellectual property. These agreements are designed in part to achieve standardization of legal system treatment of intellectual

19. Zvi Griliches (1979) discusses a number of the relevant issues. Some of the papers in this volume, notably Mansfield and Ben-Zion, reflect concern for these points.

20. The richest data set is that provided by INPADOC (1981). Patents by IPC for some fifty countries are now available for recent years. One can trace families of patents (i.e., the same patent granted in a number of different countries), firm assignments, and data on renewals.

property rights and to lower the costs of intercountry recognition of these rights. Implicitly, these international conventions seek to provide global (or as much of the globe as possible) property rights to inventors in a particular country. This may be a perfectly reasonable trade agreement between certain countries (e.g., EEC countries). We have observed in this paper, however, that trade in intellectual property is a very unequal trade, with developing countries having a strong competitive disadvantage in supplying intellectual property to developed country markets. Their inventors do not have the economic laboratories and other resources to enable them to be competitive.

Ironically, nations do not recognize global property rights in nonintellectual property and regularly intervene in commodity and capital trade markets to achieve nationalistic goals. With few exceptions, these same nations have joined international conventions freely granting intellectual property rights to citizens of other countries. By doing so they have gained some advantages in bargaining with multinational firms and in some forms of technology purchase. But unless the cost of "pirating" inventions is very high they have paid more than necessary for technology purchased from abroad.

However, the most serious impact of membership in international conventions may well be that it restricts the flexibility of many countries to design legal systems tailored to their comparative advantage, particularly regarding adaptive invention and the encouragement of indigenous secondary technology core development. Petty patent systems appear to be one alternative; there are probably others.

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Comment Frederic M. Scherer

Professor Evenson has brought together a fascinating set of data on patents and scientific and engineering employment in a broad cross section of nations.

His most interesting finding is the apparent decline, with the notable exceptions of Japan and West Germany, in patenting per scientist and engineer between the late 1960s and 1970s. This supposedly occurred because the pool of inventive possibilities became depleted. I find his explanation consistent with my own qualitative observations on what happened in a number of industries that experienced technological booms and then entered a period of apparent maturity (Scherer 1978). Nevertheless, some critical questions must be raised about what the data mean.

If indeed the pool of inventive possibilities became "fished out," one might suppose there would be increased effort to catch the same fish. Given the way the patent system works, this might show up in an increased incidence of "interferences"—that is, two or more parties claiming to have made the same invention. Changes in the rules governing interference proceedings under the U.S. patent system permit a comparable time series dating back only to 1966. This, however, spans the period analyzed by Evenson. The evidence runs contrary to the increasing interference hypothesis. From 1966 to 1970, five interferences were declared per thousand invention patent applications. (Interferences were lagged a year behind applications to reflect examination delays.) The incidence of interferences *fell* during the next five years, and by 1976–80 the average number of interferences was only three per thousand applications. It would be interesting to know whether similar patterns, seemingly at odds with the depletion theory, are observed in other industrialized nations.

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An alternative possibility is that the propensity to patent an invention of given quality fell during the 1970s. This might be so for several reasons. A number of studies (e.g., by Taylor and Silberston, [1973], Mansfield, Schwartz, and Wagner [1981] and myself [1977]) have shown that in many industries patent protection is simply not a very important component of the incentive structure underlying R & D investment. Perhaps business decision makers came to recognize this and cut back their support of patent processing activities. The relative importance of patent protection may also have declined as marketing methods became more sophisticated and "first in" image advantages served to blunt the threat of imitative R & D. Still any "declining propensity to patent" hypothesis must also come to grips with the exceptional cases, i.e., Japan and West Germany. A long-time U.S. Patent Office official insisted in 1980 that Japanese corporations were much more aggressive in seeking patent rights than their U.S. counterparts. That West Germans place special stress on the patent system's role is suggested by the existence of a large Max-Planck-Institute in Munich studying patent matters—an operation that, to the best of my knowledge, has no peer elsewhere in the world. Yet all this is highly speculative. One would like to have firmer evidence, if possible, on whether systematic changes have occurred over time in national propensities to patent.

Before we can even begin to make such advances, we must have a clearer idea of what it is patents protect and what kinds of activities give rise to patentable "inventions." Evenson argues that applied research, as contrasted to "adaptive" research or the testing and pilot plant work of development, is the most important source of invention patents. I question whether this is so. My analysis of the Xerox Corporation's patent portfolio indicated, for example, that the vast majority of Xerox patents stemmed from activities that were clearly developmental in nature (Scherer 1977, p. 9). And as the bleary-eyed reviewer of some 15,000 patent abstracts in connection with research described elsewhere in this volume, I was struck by how narrowly incremental (adaptive?) most "inventions" are. To the extent that I am right, it becomes less clear why developing nations largely confined to adaptive work generate so few patents. Perhaps what matters is not whether inventive activity is adaptive, but whether the adaptation occurs near or far behind the frontier of what has previously been accomplished. Much of the inventive activity in developing nations may well be obvious to one having ordinary skill in the art, as U.S. patentability precedents put it. The real problem could be that few people are skilled in the art. Further research on what activities yield patentable invention (e.g., extending some of the investigations described in Professor Mansfield's paper in this volume) would be desirable.

Whether or not recent patenting trends reveal significant depletion of inventive possibilities, it seems probable to me that sooner or later such a depletion effect must be observed. Following Terleckyj (1974) and others, a standard approach in studying the contibution of R & D to productivity growth is to estimate the following cross-sectional relationship based upon production function theory:

$$\text{(1)} \qquad \text{TFP} = \frac{\dot{Q}}{Q} - \alpha\frac{\dot{K}}{K} - \beta\frac{\dot{L}}{L} = \lambda + \frac{\partial Q}{\partial R}\frac{\dot{R}}{Q},$$

where all variables are in logarithms, dots indicate time derivatives, λ is an exogenous shift parameter, Q is output, R is the stock of knowledge acquired through research and development, and the other variables are as conventionally interpreted. The last term is of central interest. $\partial Q/\partial R$ is the marginal product of additions to the R & D knowledge stock. $\dot{R}$ is the annual increase in the knowledge stock; assuming no depreciation, it is simply the annual *rate* of R & D spending. Between 1953 and 1969, real R & D effort in the United States was growing at about 6 percent per year. If one can believe the more heroic extrapolations of de Solla Price (1963, chap. 1), scientific and engineering activity has been growing at this rate for two-and-a-half centuries. Meanwhile, output per hour of work (the left-hand side of equation (1) without the $\dot{K}/K$ term) has been growing at an average annual rate of about 2 percent over the past century—the longest period for which we have tolerable data. The question arises: Is there some law of nature requiring that we increase scientific and engineering activity (undepreciated $\dot{R}$) by 6 or so percent per year to sustain labor productivity growth of 2 percent per year? That is what equation (1) and the estimated component magnitudes imply. If they are correct, we are heading for trouble, for as de Solla Price observed (1963, p. 19):

> It is clear that we cannot go up another two orders of magnitude as we have climbed the last five. If we did, we should have two scientists for every man, woman, child, and dog in the population. . . . Scientific doomsday is therefore less than a century distant.

The main way out seems to be to increase the marginal product of R & D or, given the market's tendency to equalize yields at the margin, its inframarginal counterpart (i.e., the average productivity of R & D). How can that be done? One possibility that may be less far-out than one might suppose is to utilize rapidly evolving knowledge on the biochemistry of mental processes to enhance scientific creativity. Another nearer the province of economic analysis, and consistent with some of Mansfield's recent findings, may be to secure a better allocation of resources between basic research, with its substantial externalities, and applicationsoriented R & D. Or third, R & D resource allocation might be improved by effecting a better international division of labor.

Evenson's patent data provide some indication that such a division of labor is beginning to emerge. His impressions are consistent with the results of a more elaborate analysis by Slama (1981) of the Osteuropa Institute in Munich. Slama fitted a gravitational regression model to both patent and conventional trade flows data for a sizeable cross section of nations. He discovered that intercountry patenting and trade flows were greater, the larger the nations in a pair were and the smaller the geographic distance separating them. The distance slope coefficients were larger for conventional trade than for patents, the latter being much less costly than goods to "transport." Like Evenson, Slama found a significantly higher propensity to trade within the Soviet bloc planned economies than between East and West. Thus, we are beginning to find out something about the international division of labor in advancing technology. However, much more remains to be learned, especially about how market processes encourage or discourage the division of scientific and engineering labor and how much untapped potential for improving the productivity of R & D that division of labor offers.

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